MECH 591 Gas Dynamics

Spring 2021

Instructor: Professor P. Rodi, (Patrick.Rodi@rice.edu)
Class Hours: Monday/Wednesday/Friday, 5:15pm - 6:10pm, on-line (for now).
Office Hours: Monday/Wednesday/Friday, 4:00pm - 5:00pm, on-line (for now).
Course URL: https://canvas.rice.edu/courses/22262

Course Outcomes Expected:
Students completing the course should be able to:

1. Derive and apply the basic supersonic one- and two-dimensional shock and expansion-wave relations
2. Derive and apply the transonic similarity relation
3. Derive the basic shock and expansion-wave relations and apply local surface inclination methods for inviscid flowfields.
4. Describe the aerothermodynamic environment and estimate the aerodynamic forces and moments for a given vehicle in high speed flow.
5. Understand the principles that account for viscous interactions and the design philosophy behind the development of high speed vehicles.

Textbooks:
1. *Modern Compressible Flow* by Anderson, AIAA
2. Supplementary material from *Hypersonic and High Temperature Gas Dynamics* by Anderson, AIAA.
3. Supplementary material from *Hypersonic Aerothermodynamics* by Bertin, AIAA.

Grading: 20% Examination I
30% Examination II
50% Comprehensive Final Examination

Homeworks: Generally issued weekly, but not required or graded. Solutions will be posted.

Exams: Examination I
Examination II
Comprehensive Final Examination

Please note for Exams:
1. Points will be deducted in your exam if your submission is not clear in logic and presentation.
2. All quantities must have the correct dimensions.
3. All answers must be clearly marked (e.g., boxed or underlined).

Distribution: Engineering science, 3 credits. The course emphasizes theoretical concepts and analysis, but includes some design and synthesis techniques for supersonic and hypersonic systems that can be useful for later design projects.

ADA Notice: Any student with a disability requiring accommodations in this course is encouraged to contact the instructor after class or during office hours. Additionally, students should contact Disability Support Services in the Ley Student Center.

Syllabus

1. Syllabus & Introduction
Conservation equations, review of thermodynamics, compressibility, integral forms of the conservation equations for inviscid flows.

2. One-Dimensional Supersonic Flow
One-dimensional flow equations, normal shock relations, Hugoniot equation, heat addition, friction.

3. Two-Dimensional Supersonic Flow
Oblique shocks, detached shocks, Prandtl-Meyer expansion waves, Crocco's equation, shock-expansion theory.

4. Quasi-One-Dimensional Compressible Flow
Area-velocity relation, flow through a variable area duct, diffusers, wave reflection from a free boundary.

5. Unsteady Wave Motion
Moving normal shock wave, reflected shock wave, elements of acoustic theory, finite (non-linear) waves, incident and reflected expansion waves, shock tube relations.

6. Velocity Potential and Linearized Flow
Velocity potential equation, linearized pressure coefficient, linearized subsonic flow, linearized supersonic flow, area ruling.

7. Wave Propagation and Sonic Boom
Physical aspects, simple methods, Witham's F-function, computational approaches, boom shaping and suppression methodologies.

8. Conical Flow
Physical aspects, solution formulation (Taylor-Maccoll), numerical procedure.

9. Numerical Modeling of High Speed Flows
Solver types, Reynolds and Favre' averaging, compressible turbulence models.

10. Hypersonic Aerodynamics
Physical phenomena, trends with increasing Mach number, approximate solutions, local surface inclination methods, exact methods, viscous interactions, shock wave/boundary layer interactions.

11. Aerothermodynamics
Stagnation point heating, laminar and turbulent heating, boundary layer transition, compressibility of turbulence.

12. High Temperature Gas Dynamics
Local thermodynamic and chemical equilibrium, dissociation & ionization effects on "gamma," frozen flow, non-equilibrium flow.

13. Non-Continuum Flow
Continuum flow, transitional flow, free molecule flow.

14. High Speed Vehicle Design
Vehicle design drivers, conical body modeling process, lifting body modeling process, waveriders, Thermal Protection System materials.